STATE OF TENNESSEE
DEPARTMENT OF ENVIRONMENT AND CONSERVATION

DIVISION OF UNDERGROUND STORAGE TANKS

TECHNICAL GUIDANCE DOCUMENT - 015

EFFECTIVE DATE - August 1, 1996

RE: Procedure to Obtain Closure for Sites in the Monitoring Only Program

The purpose of this Technical Guidance Document (TGD) is to provide the owner and/or operator with the minimum requirements to obtain closure at petroleum underground storage tank sites in accordance with Rule 1200-1-15-.06(6)(b). This TGD shall determine an off-site point of compliance and the maximum contamination which may reach that point using Fate and Transport equations. The site may be eligible for closure after a minimum of two years of monitoring if the ground water contamination at the established point of compliance is at or below the applicable cleanup levels of 0.070 PPM benzene and 1.0 PPM TPH.

A. Determine the Distance to the Point of Compliance

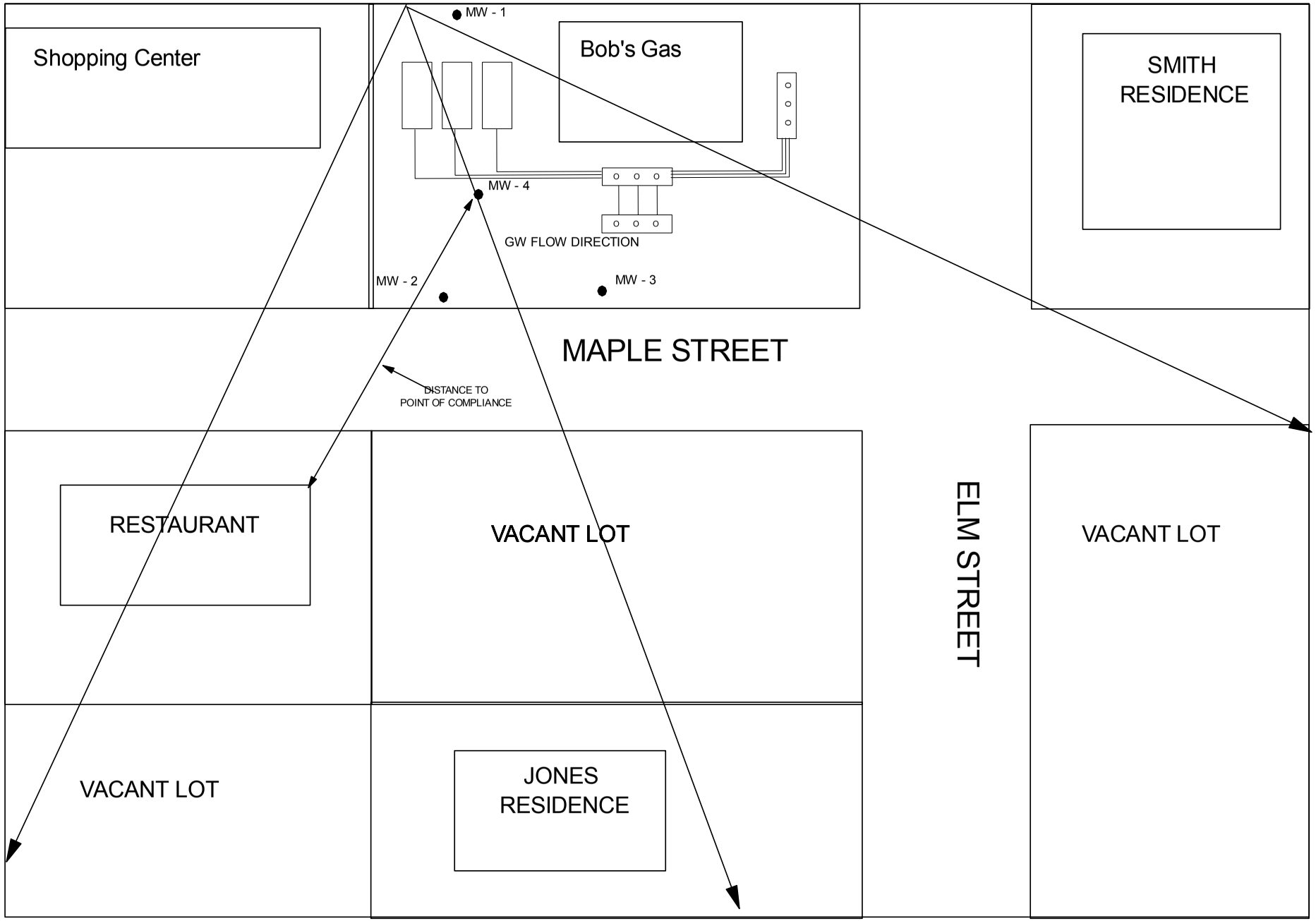
The nearest off-site occupied building (residential or commercial) from the monitoring well with the highest level of contamination, within the area specified below shall be defined as the point of compliance for the purposes of this TGD.

1. Draw a line depicting the predominant ground water flow direction on a vicinity map. The line shall start at the upgradient property line of the petroleum site, pass through the monitoring well with the highest level of contamination and extend downgradient to the edge of the map. If the highest level of benzene and TPH contamination exist in different monitoring wells, the line shall pass through the well with the highest benzene contamination.

2. Draw two (2) lines, each 45 degrees in the downgradient direction, off the ground water flow direction line. These lines shall begin at the upgradient property line of the petroleum site and extend to the edge of the vicinity map. The point of compliance shall be between these two lines.

3. Measure the distance from the monitoring well with the highest level of contamination to the point of compliance. If the highest level of benzene and TPH contamination exist in different monitoring wells, the monitoring well with the highest benzene concentration shall be used.

Refer to the attached diagram for assistance when determining the distance to the point of compliance.


MW - 1
Shopping Center
Bob's Gas
SMITH
RESIDENCE
MW - 4
GW FLOW DIRECTION
MW - 2
MW - 3
MAPLE STREET
DISTANCE TO
POINT OF COMPLIANCE
RESTAURANT
VACANT LOT
ELM STREET
VACANT LOT
VACANT LOT
JONES
RESIDENCE

B. Determine the Site Ground Water Concentrations

1. Determine LF_{SW} for benzene, GRO, and DRO using the following equations:

Soil to Ground Water Leaching

$$\mathbf{LF_{sw} = \frac{K_{SW}}{\alpha}}$$

Soil to Leachate Partition:

$$\mathbf{K_{sw} = \frac{\rho_s}{\theta_{ws} + k_s\rho_s + H\theta_{as}}}$$

Soil-Water Sorption Coefficient:

$$\mathbf{k_s = k_{oc}\ x\ f_{oc}}$$

Leachate to Ground Water Dilution Factor:

$$\alpha = 1 + \frac{\mathbf{U_{gw}\delta_{gw}}}{\mathbf{I_{m\,od} \times Sw}}$$

Site Specific Infiltration Rate:

$$\mathbf{I_{site} = I\ x\ (1 - I_{Cover})}$$

Where:

LF_{sw} Leaching Factor: Soil to ground water [(mg/L-H_2O)/(mg/kg-soil)]
K_{sw} Soil to Leachate Partition (unitless)
α Leachate to ground water dilution factor (unitless)
ρ_s Soil bulk density (g-soil/cm^3-soil)
Default value = 1.70E+00 (if ρ_s analysis has not been performed at the site)
θ_{ws} Volumetric water content in vadose zone soils (cm^3-H_2O/cm^3-soil)
Default value = 1.20E-01 (if θ_{ws} analysis has not been performed at the site)
k_s Soil-water sorption coefficient (g-H_2O/g-soil)
k_{oc} Carbon-water sorption coefficient (cm^3-H_2O/g-Carbon)
Benzene 3.80E+01
GRO 4.79E+02 (Hexane)
DRO 1.29E+03 (Naphthalene)
f_{oc} Fractional organic carbon
Default value = 1.00E-02 (if f_{oc} analysis has not been performed at the site)
H Henry's law constant
Benzene 2.20E-01
GRO 5.07E+00 (Hexane)
DRO 4.90E-02 (Naphthalene)

θ_{as} Volumetric air content in vadose zone soils (cm^3-air/cm^3-soil)
Default value = 2.60E-01(if θ_{as} analysis has not been performed at the site)

U_{gw} Ground water Darcy velocity (cm/yr)

δ_{gw} Ground water mixing zone thickness (cm)
Default value = 2.00E+02

I Infiltration rate of water through soil (cm/yr)
Default value = 3.00E+01

I_{Cover} Percent of soil contaminant plume covered by pavement, concrete, or building(s), etc. If the entire soil contaminant plume is covered the maximum allowable number is 90%.

I_{site} Site specific infiltration rate of water through soil (cm/year)

S_W Width of source area parallel to ground water flow direction (cm)
Default value = 1.50E+03 (if S_W was not determined in the ISCR)

2. Determine $C_{Leaching}$ using the following equation for benzene, GRO, and DRO.

$$\mathbf{C_{Leaching} = C_{soil\ ave} \times LF_{sw}}$$

Where:

$C_{Leaching}$ Contamination in ground water contributed by leaching (PPM)

$C_{soil\ ave}$ Average soil contamination taken from the boring installed during the most recent soil monitoring event (PPM). If any of the soil samples were non-detect they shall not be used in the calculation.

3. Determine $C_{gw\ ave}$ using the following equation for benzene and TPH using all analytical data from the three (3) most recent ground water monitoring events. If a monitoring well had non-detect results during all three (3) monitoring events, the data from that monitoring well shall not be used in the calculation. If during the last three (3) monitoring events, a monitoring well had one (1) or two (2) non-detect results, $C_{gw\ ave}$ shall be calculated assigning the non-detect results a value of zero (0).

$$\mathbf{C_{gw\ ave} = \sum \frac{C_{N\ MW}}{N}}$$

Where:

$C_{gw\ ave}$ Average site ground water contamination (PPM)

$C_{N\ MW}$ Contamination in monitoring well for sample N (PPM)

N Number of samples

4. Determine C_{Source} using the following equations for benzene and TPH.

a. $C_{Source\ benzene} = C_{Leaching\ benzene} + C_{gw\ ave\ benzene}$

b. $C_{Source\ TPH} = C_{Leaching\ GRO} + C_{Leaching\ DRO} + C_{gw\ aveTPH}$

C. Determine the concentration at the point of compliance for benzene and TPH using the following equation:

$$\frac{C_x}{C_{source}} = \mathbf{erf}\left(\frac{S_w}{4\sqrt{\alpha_y x}}\right) \times \mathbf{erf}\left(\frac{S_d}{4\sqrt{\alpha_z x}}\right)$$

Where:

C_x	Concentration at the point of compliance (PPM)
C_{source}	Contamination at the site (PPM)
S_d	Source depth (cm) Default = 2.00E+02
x	Distance to point of compliance (cm)
$\alpha_x = 0.10x$	Longitudinal Dispersivity (cm)
$\alpha_y = \frac{\alpha_x}{3}$	Transverse Dispersivity (cm)
$\alpha_z = \frac{\alpha_x}{10}$	Vertical Dispersivity (cm)

An Error Function Table has been provided below to assist in determining the erf value. If an Error Function Table is used, extrapolation shall be used to determine the exact erf value. However, several spreadsheet software packages are capable of determining the value directly.

Error Function (erf) Table

β	erf (β)	β	erf (β)
0.00	0	1.0	0.842701
0.05	0.056372	1.1	0.880205
0.10	0.112463	1.2	0.910314
0.15	0.167996	1.3	0.934008
0.20	0.222703	1.4	0.952285
0.25	0.276326	1.5	0.966105
0.30	0.328627	1.6	0.976348
0.35	0.379382	1.7	0.983790
0.40	0.428392	1.8	0.989091
0.45	0.475482	1.9	0.992790
0.50	0.520500	2.0	0.995322
0.55	0.563323	2.1	0.997021
0.60	0.603856	2.2	0.998137
0.65	0.642029	2.3	0.988857
0.70	0.677801	2.4	0.999311
0.75	0.711156	2.5	0.999593
0.80	0.742101	2.6	0.999764
0.85	0.770668	2.7	0.999866
0.90	0.796908	2.8	0.999925
0.95	0.820891	2.9	0.999959
		3.0	0.999978

D. Determine if the site is eligible for closure

Compare the concentrations at the point of compliance for benzene and TPH with the applicable cleanup levels of 0.070 PPM benzene and 1.0 PPM TPH. If the concentrations at the point of compliance are at or below the applicable cleanup levels, the site may be eligible for closure upon approval by the Division.

If the site is not eligible for closure, the owner and/or operator shall continue with the monitoring only program until such time as the concentrations at the point of compliance are below the applicable cleanup levels.

E. Determine the target site cleanup goal(s), if applicable.

If the contaminant levels at the point of compliance exceed the applicable cleanup levels, determine the target site cleanup goal(s) necessary to achieve 0.070 PPM benzene and/or 1.0 PPM TPH at the point of compliance. This shall be done by using the equation in section C. above and solving for C_{Source}.

After two (2) years of monitoring the petroleum site and after each subsequent monitoring event, the average site ground water contamination shall be determined using the equation in section B.3. above. This contamination shall be compared to the target site cleanup goal(s) established above. At such time, the site average ground water contamination is at or below the target site cleanup goal(s), the site may be eligible for closure upon approval by the Division.

F. Report Preparation

After the site has been in the Monitoring Only Program for two years, the attached Closure Report for Monitoring Only Sites shall be submitted with the fourth Site Status Monitoring Report or as directed by the Division. The report shall not be resubmitted until the site average ground water contamination is at or below the target site cleanup goal(s).

Reference: ASTM Standard: E 1739-95 Standard Guide for Risk-Based Corrective Action Applied at Petroleum Sites

STATE OF TENNESSEE
DEPARTMENT OF ENVIRONMENT AND CONSERVATION
DIVISION OF UNDERGROUND STORAGE TANKS
CLOSURE REPORT FOR MONITORING ONLY SITES

1. Facility ID #:__-__ __ __ __ __ __

2. Facility Name:

3. Date site approved for monitoring only:

4. Provide a description of the point of compliance (i.e. residence, business). Attach a vicinity map showing its location and the distance to the monitoring well with the highest level of contamination.

5. List the following parameters used in the calculations:

Parameter	Value	Units
ρ_s		g-soil/cm^3-soil
θ_{ws}		cm^3-H_2O/cm^3-soil
f_{oc}		percent
θ_{as}		cm^3-air/cm^3-soil
U_{gw}		cm/yr
S_W		cm
I_{Cover}		percent
x		cm

6. List the benzene ground water concentrations, in PPM, from the 3 most recent sampling events:

	Event 1	Event 2	Event 3
Date of sampling event	/ /	/ /	/ /
Well Number			

7. List the TPH ground water concentrations, in PPM, from the 3 most recent sampling events:

	Event 1	Event 2	Event 3
Date of sampling event	/ /	/ /	/ /
Well Number			

8. Provide $C_{soil\ ave}$ for benzene, GRO, and DRO, in PPM. Include document, date, and page number where information can be verified.

	Benzene	GRO	DRO
Date of sampling event:	/ /	/ /	/ /
Sample 1			
Sample 2			
Sample 3			
Average			

9. Attach worksheets showing the calculations for the following:

a. I_{site}
b. α
c. k_s for benzene, GRO, and DRO
d. K_{sw} for benzene, GRO, and DRO
e. LF_{sw} for benzene, GRO, and DRO
f. $C_{soil\ ave}$ for benzene, GRO, and DRO
f. $C_{Leaching}$ for benzene, GRO, DRO
g. $C_{gw\ ave}$ for benzene and TPH
h. C_{Source} for benzene and TPH
i. α_x
j. α_y
k. α_z
l. C_x for benzene and TPH

10. Provide the results of the calculations in the following table:

Parameter	Value	Units
I_{site}		cm/yr
α		unitless
$k_{s\ benzene}$		g-H_2O/g-soil
$k_{s\ GRO}$		g-H_2O/g-soil
$k_{s\ DRO}$		g-H_2O/g-soil
$K_{sw\ benzene}$		unitless
$K_{sw\ GRO}$		unitless
$K_{sw\ DRO}$		unitless
$LF_{sw\ benzene}$		(mg/L-H_2O)/(mg/kg-soil)
$LF_{sw\ GRO}$		(mg/L-H_2O)/(mg/kg-soil)
$LF_{sw\ DRO}$		(mg/L-H_2O)/(mg/kg-soil)
$C_{soil\ ave\ benzene}$		PPM
$C_{soil\ ave\ GRO}$		PPM
$C_{soil\ ave\ DRO}$		PPM
$C_{Leaching\ benzene}$		PPM
$C_{Leaching\ GRO}$		PPM
$C_{Leaching\ DRO}$		PPM
$C_{gw\ ave\ benzene}$		PPM
$C_{gw\ ave\ TPH}$		PPM
$C_{Source\ benzene}$		PPM
$C_{Source\ TPH}$		PPM

α_x		cm
α_y		cm
α_z		cm
$C_{x\ benzene}$		PPM
$C_{x\ TPH}$		PPM

11. Determine if the site is eligible for closure:

	Benzene	TPH
Calculated concentrations at the point of compliance		
Applicable cleanup levels	0.070 PPM	1.0 PPM
Is the calculated concentration below the applicable cleanup level? (Yes/No)		

12. Determine target site cleanup goal(s) for benzene and TPH, if applicable:

Attach worksheets showing the calculations for the target site cleanup goal(s) for benzene and TPH

Benzene target site cleanup goal (PPM)	
TPH target site cleanup goal (PPM)	

A signature page, as shown below shall be attached to the Closure Report For Monitoring Only Sites Form only if it is not submitted with any other report. The page shall be signed by the owner/operator (or authorized representative within the organization) and a registered professional geologist under the Tennessee Geologist Act (*T.C.A. §62-36-101 et seq*.), or a registered professional engineer under the Tennessee Architects, Engineers, Landscape Architects, and Interior Designers Law and Rules (*T.C.A. §62-2-101 et seq*.).

We, the undersigned, certify under penalty of law, including but not limited to penalties for perjury, that the information contained in this report form and on any attachments, is true, accurate and complete to the best of our knowledge, information, and belief. We are aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for intentional violations.

_____	_____	_____
Owner/Operator (Print name)	Signature	Date
	_____	
	Title (Print)	
_____	_____	_____
P.E. or P.G. (Print name)	Signature	Date
	_____	
	Tennessee Registration #	

Note: Each of the above signatures shall be notarized separately with the following statement.

STATE OF _____ COUNTY OF _____

Sworn to and subscribed before me by _____on this date

_____. My commission expires _____.

_____	_____	_____
Notary Public (Print name)	Signature	Date

Stamp/Seal

Procedures to run TGD-015.XLS

The Division of Underground Storage Tanks has developed a spreadsheet in Microsoft Excel version 5.0 to perform all of the calculations in accordance with Technical Guidance Document -015, Procedures to Obtain Closure for Sites in the Monitoring Only Program.

Getting Started

Prior to loading the spreadsheet in Excel, it will be necessary to determine if the Analysis ToolPak has been installed on the computer. To determine this, choose Add-Ins... from the Tools menu and see if Analysis ToolPak is an option to activate. If it is present, check the box to the left of Analysis ToolPak, then click on OK.

If the program does not exist in the above sub-directory it will be necessary to run the Setup program, from the installation disks, to install the Analysis ToolPak. After installing the Analysis ToolPak activate it by performing the steps in the above paragraph.

The Analysis ToolPak will enable the spreadsheet to calculate the erf value in the Domenico Ground Water Solute Transport Model. Without it properly installed, the spreadsheet will not work.

Entering the Data

Open the spreadsheet named tgd-015.xls.

1. General Facility Information

   The general facility information shall be entered in items 1-4. Invisible text boxes have been provided to enter the information into. To access the text box for item 1, use the mouse to click on the area after the provided text. Type the appropriate text into the box, then hit the Tab button to proceed to the next text boxes.

2. Site Specific Facility Data

   Enter the site specific facility data in the cells provided in item 5 of the spreadsheet in accordance with the guidance in TGD-015. These eight (8) cells have been formatted to three (3) decimal places and data must be present in each cell for the spreadsheet to perform the calculations.

3. Benzene Groundwater Data

   Enter the appropriate benzene groundwater data in the cells provided in item 6 of the spreadsheet in accordance with the guidance in TGD-015. The well identification and dates of the sampling events shall also be entered. The spreadsheet will automatically calculate the benzene site groundwater average

concentration. If there is not any benzene contamination on the site, a zero (0) shall be entered into one of the concentration cells to indicate that fact.

4. Total Petroleum Hydrocarbon (TPH) Groundwater Data

Enter the appropriate TPH groundwater data in the cells provided in item 7 of the spreadsheet in accordance with the guidance in TGD-015. The well identification and dates of the sampling events shall also be entered. The spreadsheet will automatically calculate the TPH site groundwater average concentration. If there is not any TPH contamination on the site, a zero (0) shall be entered into one of the concentration cells to indicate that fact.

5. Site Specific Soil Data

Enter the appropriate site soil data for benzene, GRO, and DRO in the appropriate cells provided in item 8 of the spreadsheet in accordance with the guidance in TGD-015. The sampling point location and dates of the sampling shall also be entered. The spreadsheet will automatically calculated the site soil average concentrations for benzene, GRO, and DRO. If there is not any benzene, GRO, and/or DRO contamination on the site, a zero (0) shall be entered into one of the appropriate soil concentration cells to indicate that fact.

This is all of the data which is necessary to determine the calculate concentrations at the point of compliance. Once the data has been entered the results can be viewed on the computer or printed.

The spreadsheet needs to be saved as a spreadsheet with a different name so that tgd-015.xls is available as a blank spreadsheet to enter data for additional sites.